3.5.1 Newton's laws of motion

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	Newton's three laws of motion	HSW7
(b)	linear momentum; $p = mv$; vector nature of momentum	
(c)	net force = rate of change of momentum; $F = \frac{\Delta p}{\Delta t}$	Learners are expected to know that $F = ma$ is a special case of this equation. HSW9, 10 *M2.1, M3.9*
(d)	impulse of a force; impulse = $F\Delta t$	
(e)	impulse is equal to the area under a force–time graph.	Learners will also be expected to estimate the area under non-linear graphs. HSW3 Using a spreadsheet to determine impulse from *F*–*t* graph. *M3.8, M4.3*

3.5.2 Collisions

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the principle of conservation of momentum	HSW7
(b)	collisions and interaction of bodies in one dimension and in two dimensions	Two-dimensional problems will only be assessed at A level. HSW11, 12
(c)	perfectly elastic collision and inelastic collision.	HSW1, 2, 6

(6) M - Recall the law of conservation of momentum
(7) S - Apply the equation for linear momentum.
(8) C - Analysis collisions that occur in 2 dimensions.

Collisions in 2D

STARTER: A truck of mass 50 kg travelling with a velocity of 3.0 m s–1 collides with a stationary truck of mass 30 kg and **they move on together**.

a Calculate their velocity after the collision.
b Is the collision elastic or inelastic?

Extension: Try Lowe ex7.6

a *Step 2*

Find the velocity after collision by applying the law of conservation of momentum.

$$m_1 u_1 + m_2 u_2 = (m_1 + m_2) v$$

$$(50 \times 3.0) + (30 \times 0) = (50 + 30) v$$

$$150 + 0 = 80 v$$

$$v = \frac{150}{80}$$

$v = 1.9\ \text{m s}^{-1}$ (to two significant figures)

b *Step 3*

To decide whether the collision is elastic or inelastic, you need to calculate the kinetic energy before and after the collision, and compare the values.

$$E_K = \frac{1}{2} m v^2$$

Before collision:

$$E_K = \frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2$$

$$= (\frac{1}{2} \times 50 \times 3^2) + (\frac{1}{2} \times 30 \times 0^2)$$

$$= 230\ \text{J}$$

(6) M - Recall he law of conservation of momentum
(7) S - Apply the equation for linear momentum.
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Reminder.....

23 When a gardener aims water from a hosepipe at the ground, he notices that the water always splashes in many directions. Fig. 22.1 shows the splashes produced by a vertical jet of water hitting the ground.

→ horzontal momentum before Splash = zeo.

→ Total momentum in a specific direction is constant.

Fig. 22.1

→ Water Splashing in opposite direction Means equal & opposite Moment in opposite direction.

(a) Using ideas about momentum explain why the water splashes in many directions.

....

The total momentum is **a specifc direction** remains constant, as long as no external forces act.

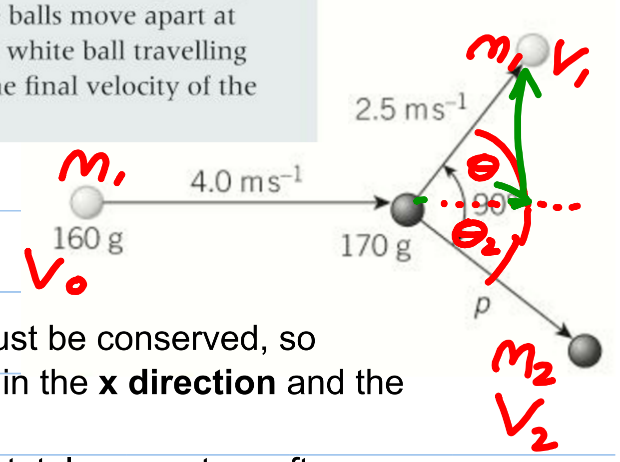
(6) M - Recall he law of conservation of momentum
(7) S - Apply the equation for linear momentum.
(8) C - Analysis collisions that occur in 2 dimensions.

Snooker example - Resolving momentum

Worked example: Snooker balls

A 160 g white ball travelling at $4.0\,\mathrm{m\,s^{-1}}$ hits a stationary 170 g black ball (Figure 3). After the impact, the balls move apart at approximately 90° to each other, with the white ball travelling at $2.5\,\mathrm{m\,s^{-1}}$. Calculate the magnitude of the final velocity of the black ball.

[redacted] [redacted]



1. The momentum in any direction must be conserved, so momentum must remain the same in the **x direction** and the **y direction**.
2. In x: The total momentum before = total momentum after.

[redacted]

$$m_1 v_0 = m_1 v_1 \cos\theta_1 + m_2 v_2 \cos\theta_2$$

$V_{2x} = 2.97\ \mathrm{ms^{-1}}$

3. In y: The total momentum before = total momentum after. [redacted]

[redacted]

$$0 = m_1 v_1 \sin\theta_1 + m_2 v_2 \sin\theta_2$$

$V_{2y} =$

4. **check this Q - seems wrong - check angles**

change question.

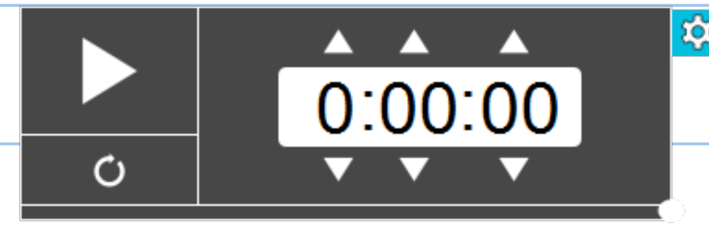
0:00:00

(6) M - Recall the law of conservation of momentum
(7) S - Apply the equation for linear momentum.
(8) C - Analysis collisions that occur in 2 dimensions.

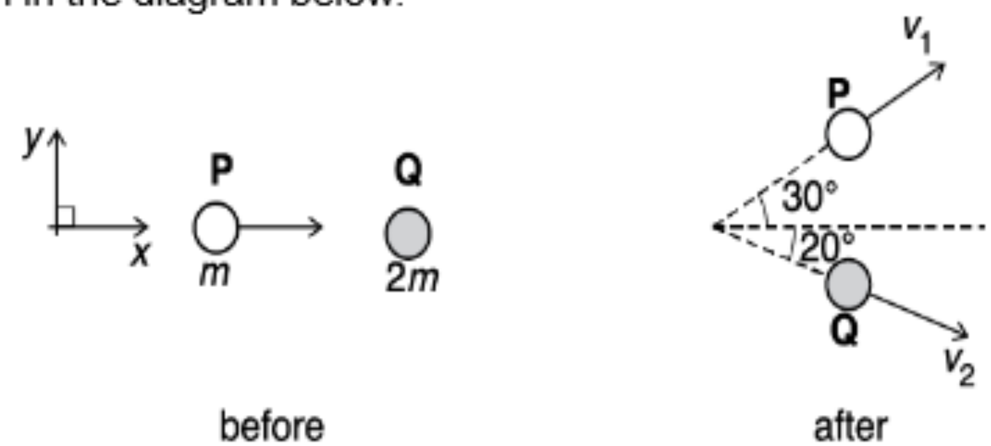
ACTIVITY 1: Complete the summary questions
ACTIVITY 2: Complete Q8 P113

Extension: Try Lowe ex7.6

(6) M - Recall he law of conservation of momentum
(7) S - Apply the equation for linear momentum.
(8) C - Analysis collisions that occur in 2 dimensions.



A ball **P** of mass m has a velocity in the positive x-direction. It makes a collision with a stationary ball **Q** of mass $2m$. After the collision, the ball **P** has velocity v_1, ball **Q** has velocity v_2 and the balls travel in the directions shown in the diagram below.



After the collision, the total momentum of the balls in the x-direction is p_x and the total momentum in the y-direction is p_y.

Which row is correct for p_x and p_y?

	p_x	p_y
A	$2mv_2 \cos 20° + mv_1 \cos 30°$	0
B	$2mv_2 \sin 20° + mv_1 \sin 30°$	0
C	$2mv_2 \cos 20° + mv_1 \cos 30°$	$2mv_2 \sin 30° + mv_1 \sin 20°$
D	$2mv_2 \sin 20° + mv_1 \sin 30°$	$2mv_2 \cos 30° + mv_1 \cos 20°$